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Measuring public perception and preferences for ecosystem services: A case study of bee pollination in the UK

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ABSTRACT

There is concern that insect pollinators, such as bees, are currently declining in abundance, and are under serious threat from factors such as increased use of certain pesticides, land use changes, competition from invasive alien species, pathogens, parasites and climate change. Using the contingent valuation (CV) method, this paper evaluates how much public support there would be in preventing further decline to maintain the current number of bees by estimating the willingness to pay (WTP) for a theoretical bee protection policy in the UK. We apply the CV method as an estimation of public perception and preferences for pollination services. The mean WTP to support the bee protection policy was approximately £43 per household per year. Based on the 30.6 million taxpayers in the UK, this is equivalent to £842 million per year. This value can provide a means of illustrating the total value of public support for maintaining pollination services to policy makers and stakeholders.

1. Introduction

Pollination is a keystone biological process in both managed and natural terrestrial ecosystems. Without pollination many inter-connected species inhabiting, and processes functioning within, an ecosystem would collapse (Kearns et al., 1998; Nabhan and Buchmann, 1997). As an ecosystem service, pollination directly or indirectly provides multiple benefits, for example, aiding in genetic diversity, contributing to ecosystem resilience and nutrient recycling, supporting our survival and quality of life (Daily, 1997), as well as the more obvious economic benefit of increasing the productivity of agricultural crops (Nabhan and Buchmann, 1997; MA, 2005; Ollerton et al., 2011).

The majority of agricultural crops depend on animal pollination (Klein et al., 2007; Aizen et al., 2009) and pollination services are provided by a variety of wild and commercially managed animal species including bees, moths, beetles, wasps, flies, birds, butterflies and bats (Ollerton et al., 2011). Globally, it is estimated that 84% of the approximately 300 commercial crops are insect pollinated (Williams, 1996), with fruits, vegetables, oilseeds, legumes and fodder, mostly pollinated by bees (Free, 1993). In the UK, at least 39 crops grown for fruit or seed are insect pollinated, with a further 32 crops requiring insects for propagation of seed production (Williams, 1994).

Bees play a major role in pollination of a wide range of fruit, vegetable and arable crops in the UK (Breeze et al., 2011). In particular, honeybees have historically been regarded as the most economically important group of pollinators (Free, 1993; Williams, 1994, 1996; Kremen et al., 2007; NRC, 2007) although subsequent data concerning wild bees and other insects has emerged, challenging the relative importance of honeybees (e.g. Winfree et al., 2008; Garibaldi et al., 2011, 2013).

Over the past few decades, there have been significant declines in the number of feral and managed bees globally (Biesmeijer et al., 2006; NRC, 2007; Potts et al., 2010; Carvalheiro et al., 2013). The decline is attributed to a number of factors such as increased use of certain pesticides (VanEngelsdorp et al., 2009; Whitehorn et al., 2012; di Prisco et al., 2013; Goulson, 2013), land use changes (Winfree et al., 2009; Osgathorpe et al., 2011), introduction of invasive species (Sugiura et al., 2013), pathogens and parasites (Vanbergen et al., 2013) and climate change (Potts et al., 2010; vanEngelsdorp and Meixner, 2010; Franzen and Ockinger, 2012). In the UK the pollination of crops by honeybees has been reported to be in decline, with decline in colony numbers being linked with use of particular insecticides (Budge et al., 2015).

To support the protection of bees, it is important that the economic value of the services they provide to society is established. This requires a brief discussion of the different types of values of pollination services.

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Based on the total economic value (TEV) concept (Perman et al., 2011), the economic value conferred by pollination services can be classified into three main components: (1) use values, (2) option values, and (3) non-use values. Use value reflects the direct use of the pollination services. Option value reflects the value individuals place on a future ability to use the resource. Non-use value is a value placed on an environmental good and which is unrelated to any actual, planned or possible use of the good (Perman et al., 2011). These values can further be categorised as having market and non-market values. Market values consist of the contribution they make to the production of a range of agricultural crops (Ricketts et al., 2004; Gallai et al., 2009; Kasina et al., 2009; Bauer and Wing, 2010). Non-market values arise from the utility which individuals derive from seeing pollinators (i.e. use value) or simply knowing that they exist and the aesthetic value of wild flowers which require pollination (non-use or existence values) (Hanley et al., 2015).

There are a number of economic approaches that can be used to estimate the value of pollination services including (Bauer, 2014): (1) the estimation of the value of crop production that can be attributed to insect pollination, (2) estimation of changes to producer and consumer surplus—using a production function, (3) the replacement cost method, and (4) contingent valuation and choice modelling. Some of these methods provide a theoretically consistent measure of consumer and producer surplus (e.g. production function) while others lead to approximations (e.g replacement cost).[1] Note that these valuation methods measure different aspects of the value of pollination services and are appropriate at different scales. A more detailed discussion of these methods can be found in a number of reviews and guidelines (see Mburu et al., 2006; Hein, 2009; Kasina et al., 2009; Winfree et al., 2011; Bauer, 2014; Hanley et al., 2015). In this paper we focus on the estimation of non-market values of pollination services.

A number of studies have analysed the economic value of pollination services at the national level, mostly focussed on developed countries e.g. Australia (Gordon and Davis, 2003), UK (Carreck and Williams, 1998; Smith et al., 2011), USA (Southwick and Southwick, 1992; Morse and Calderone, 2000), and a few developing countries such as South Africa (Allsopp et al., 2008) and Kenya (Kasina et al., 2009). There have also been attempts to analyse the value of the pollination service at the global level (e.g. Costanza et al., 1997, 2014; Gallai et al., 2009; Bauer and Wing, 2010). However, these studies used different approaches, resulting in different economic values of pollination services being published. For example, the value provided by the pollination service to US agriculture was estimated to be US$6 billion per year by Southwick and Southwick (1992) and US$ 14 billion per year by Morse and Calderone (2000).

Focussing on major UK crops, Carreck and Williams (1998) used the level of insect pollination dependency to estimate the production value of bees to be £172 million per year (equivalent to US$219 million) for outdoor crops and £30 million per year (US$38 million) for glasshouse crops. The same approach was used in the UK's National Ecosystem Assessment (UK NEA) to estimate the economic value of pollination for all UK crops in 2007 (Smith et al., 2011). The value of the pollination service to UK agriculture was estimated to be £430 million per annum (equivalent to US$548 million). However, these studies estimate the contribution of insect pollination service within agriculture, but do not evaluate the non-market values for pollination services.

Kleijn et al. (2015) assert that the "delivery of crop pollination services is an insufficient argument for wild pollinator conservation". Their analysis of global crop production showed that wild bees contribute (US$3251 per ha) a similar amount to honey bees (US$2913 per ha). The public support for pollinators is also largely missing from the economic literature. By definition, this public support reflects the values attached to the existence of pollinators (Breeze et al., 2015). Notwithstanding, there are few published studies of the non-market benefits of pollination services.

This study evaluates how much public support there would be in preventing further decline in order to maintain the current number of bees in the UK. Economists have developed a number of methods for estimating non-market values, broadly categorised as revealed and stated preference methods (e.g. Hanley and Barbier, 2009; Freeman et al., 2014). Revealed preference (RP) methods have the advantage of relying on actual market behaviour but they can only be applied to measure 'use' values (e.g. Kasina et al., 2009). Stated preference (SP) methods are applicable to a wide range of ecosystem goods and services and typically they are the only option available for estimating non-use values of the pollination service (Hanley et al., 2015; Breeze et al., 2015).[2] Stated preference techniques use information provided by respondents to questionnaires asking about their WTP for an environmental improvement in a hypothetical market (Mitchell and Carson, 1989; Bateman et al., 2002; Hanley and Barbier, 2009). The questions may be based on contingent valuation (CV) or choice modelling (CM).

However, SP methods also have their limitations, including hypothetical bias (Murphy et al., 2005), embedding effect and insensitivity to scope (Kahneman and Knetsch., 1992).[3] The main challenge in assessing the non-market values of pollination services using SP methods is the extent of public knowledge on pollination services (Mburu et al., 2006; Hanley et al., 2015).[4] If respondents in a CV survey are not aware of the importance of the goods that they are being asked to value, they may not reveal a strong preference and the good may be undervalued (Christie et al., 2006). However, strategies are available to reduce this problem. For example, it has been shown that providing additional information about a public good before estimating the WTP for it can lead to a significant increase in values of the respondents (LaRiviere et al., 2015).[5]

This paper applies the CV method to measure the WTP for a theoretical bee protection policy in the UK. With the limitations of SP in mind, we apply the CV method as an estimation of public perception and preferences for pollination services. Moreover, a good understanding of how the public perceives ecosystem benefits can facilitate better valuation of ecosystem services and influence policy. This article contributes to the scarce literature on evaluating the non-market values of pollination services. The results can provide a means of illustrating the overall value of conserving pollination services to policy makers and other stakeholders, in addition to setting priorities among competing conservation goals (de Groot et al., 2012; Hanley et al., 2015).

[1] Consumer surplus and producer surplus are welfare measures commonly used in economics. The consumer surplus (CS) is the difference between the willingness to pay (WTP) for a good or service and actual expenditure while the producer surplus (PS) is the difference between the revenue received for a good or service and the costs of provision of the good or service (Tietenberg and Lewis, 2015). Economic surplus is the sum of consumer surplus and producer surplus.

[2] For example, SP methods have been used to value other ecosystem services such as water quality, recreation and carbon sequestering (Ninan, 2014).

[3] A scope test is recommended as a way to test the validity of CV studies (Arrow et al., 1993). It examines whether respondents are willing to pay more for a good that is larger in scope, either in a quantity or quality sense. However, there are many reasons for the failure to pass a scope test, including diminishing marginal utility, substitution and socio-psychological factors—all of which are consistent with economic theory (see Heberlein et al., 2005). The authors conclude that, 'by itself, the scope test is neither a necessary nor sufficient condition to invalidate a CV study' (Heberlein et al., 2005). The scope test was not conducted in this CV study.

[4] For example, surveys in the UK suggest that the public does not relate easily to the concept of ecosystem services. But they appreciate the benefits of provisioning services, such as the supply of food and clean water, regulating services, and cultural services including recreation and urban green space (UK NEA).

[5] Another strategy is to use the 'learning design contingent valuation' method developed by Bateman et al. (2008). Here respondents are provided with opportunities for learning by repetition and experience. It allows for learning and experience in the valuation tasks and for the opportunity to 'discover' preferences within the duration of the survey. The authors assert that it is the last response in a series of valuations which should be attended to rather than the first. However, this strategy could not be implemented in this study due to budget constraints.

2. Methods

2.1. Contingent valuation method

The CV method is a survey-based approach for valuing non-market goods and services (Mitchell and Carson, 1989; Champ et al., 2003; Freeman et al., 2014). The approach asks people questions regarding their willingness to pay (WTP) to obtain a specified environmental good, or their willingness to accept (WTA) compensation so as to give up a good or service, rather than inferring their values from observed behaviours in regular markets. The CV method presents hypothetical scenarios to respondents in a survey format, where the scenario involves a trade-off between the amount of an environmental good and a monetary cost. By analysing the responses to such questions across individuals the average WTP per respondent can be estimated.

There are several elicitation formats within the CV framework. The dichotomous choice (DC) format is the dominant form of CV questions and has been recommended by the NOAA panel (Arrow et al., 1993) because it is incentive compatible (Carson and Groves, 2007), is a relatively easy question for the respondent to answer and it replicates real life decision-making (Vossler and Mckee, 2006). But it gives little information about the preferences of respondents. The payment card (PC) format was applied to overcome this problem. It is statistically more efficient in the estimation of parameters compared to the DC format, insensitive to starting point bias compared to the bidding game and requires lower cognitive effort than the open-ended format (Vossler and McKee, 2006; Covey et al., 2007; Mahieu et al., 2014).

Using the PC format respondents are presented with a range of bids and asked to pick the amount that represents the most they would be willing to pay. The amount chosen is a lower bound for the respondent's WTP, the upper bound being the next highest amount on the card (Cameron and Huppert, 1989). Under this formulation WTP is not directly observed, however, statistical models can be used to obtain the parameters of the distribution of WTP and to estimate the respondent's expected WTP. The current study selected the PC method as described by Mahieu et al. (2014).

The PC format involves implementing an interval regression (IR) model to estimate the mean WTP (Cameron and Huppert, 1989). The model is specified as:

$$Y_i = x'_i\beta + \varepsilon_i \tag{1}$$

where: Y_i is the respondent's value expected to lie within the interval defined by the lower and upper thresholds (B_{li}, B_{ui}); x_i is a vector of explanatory variables that affect respondents WTP; β is a vector of the coefficients to be estimated; and ε_i is the error term that is assumed to be distributed normally with mean 0 and standard deviation σ. Now for every interval threshold for Y_i, the probability that an individual selects B_{li} on the payment card is a probability that the WTP lies between B_{li} and B_{ui} as follows:

$$\Pr(Y_i \subseteq (B_{li}, B_{ui})) = \Pr((B_{li} - x'_i\beta)/\sigma) < z_i < ((B_{ui} - x'_i\beta)/\sigma) \tag{2}$$

where: z_i is the standard normal random variable. The log-likelihood function for a sample size n is specified as:

$$Log\ L = \sum_{i=1}^{n} \log[\Phi((B_{ui} - x'_i\beta)/\sigma) - \Phi((B_{li} - x'_i\beta)/\sigma)] \tag{3}$$

where Φ is the cumulative standard normal density function.

The PC format also has some potential drawbacks. The main one is that it is vulnerable to biases relating to the range of the numbers used in the card (Rowe et al., 1996; Covey et al., 2007). However, the method allows respondents to choose the value which is the most they would pay and the least they would not pay, thereby expressing 'uncertainty' of their preferences for environmental goods and services (Mahieu et al., 2014). So far, the PC approach is one of the most popular ways of eliciting WTP in the health and environmental economics literature (e.g. Covey et al., 2007; Mahieu et al., 2014).

2.2. Survey design

A CV questionnaire was designed to examine the public's WTP for a theoretical bee protection policy in the UK (i.e. bee protection policy is the 'market'). The survey instrument consisted of three sections: (1) introduction, (2) valuation questions, and (3) closing. The introduction was used to inform participants of the terminology used in the CV. The introduction provided participants with information about the importance of pollinating bees and their decline in recent years. Pictures depicting bees pollinating flowering plants was shown, so that all participants knew exactly what they were being asked to value. They were then introduced to a concept of a policy that would effectively preserve bee numbers at present levels. Respondents were asked whether they would pay to support such a policy and how much they would pay. The closing section of the survey asked a number of socio-economic and demographic questions. The questionnaire included attitudinal and behavioural questions about conservation.

A draft questionnaire was pre-tested. The objectives of the pre-test were: (1) to determine if the information, contingent program and payment method presented in the CV scenario were understandable, (2) to determine the most suitable number and levels of amounts (£) for application of the PC intervals for the full sample in the survey (Cameron and Huppert, 1989). An open-ended elicitation format was used during the pre-test, as suggested by Bateman et al. (2002). A formal pre-test of the survey was conducted using 20 participants from the Food and Environment Research Agency (Fera) in Yorkshire under the same conditions to be followed in the final survey.

As discussed earlier, the basic problem with valuing ecosystem services is the extent of public understanding of ecosystem services and the benefits they provide (e.g. Christie et al., 2006). Hanley et al. (2015) asserts that respondents may lack sufficient understanding to be able to state their preferences in terms of WTP for an environmental change. To reduce this 'knowledge problem' (LaRiviere et al., 2014), we provided information to participants to explain the importance of pollinating bees (see Appendix). In addition, the final survey was conducted with a sample that was considered to be well informed to undertake the valuation exercise. The main CV survey was administered primarily at the Great Yorkshire Show (GYS), the largest agricultural show in England, attracting more than 130,000 visitors annually.[6] We recognise that the attendees at an agricultural show do not represent a random sample of the public and so the survey sample may suffer from a selection bias.

The study opted for an in-person interview because it generally yields the highest survey response rate (Bateman et al., 2002). The survey presented participants with a scenario describing bee populations in the UK. Respondents were then asked to indicate their maximum WTP for a protection policy to maintain bee populations at current levels. Using the PC format, each respondent was confronted with a series of money amounts ranging from £0.1 to £20 per week in increments, and asked to tick their maximum WTP for the program. Different payment vehicles are used in various CV studies, depending on the nature of the good being evaluated. The payment vehicle used in this CV study was an income tax, and presented as a weekly/annual increase (Bateman et al., 2002). The reasons for using this payment vehicle include the fact that biodiversity programmes are generally paid for through taxation (Christie et al., 2006) and that it was found to be the most reasonable payment option during pre-test surveys. Respondents were clearly told that the bee protection policy would be funded through imposing an additional tax on their wages or salaries. The survey included a statement reminding respondents of their budget constraints to encourage participants to state their true values (Champ et al., 2003).[7] The CV scenario and WTP questions are summarised as

[6] For more details, please visit the following website: http://greatyorkshireshow.co.uk/

follows:

The results of several surveys suggest the number of bees in the UK has reduced in recent years, perhaps due to building on green spaces and climate change. We aim to evaluate how much public interest there would be in preventing further declines and maintaining the number of bees in the UK indefinitely.

- Q2 (a): Would you be willing to pay to support a policy to maintain bee populations at the current level? Tick your response: ___Yes ___No.
- Q2 (b): If YES, how much would you be willing to pay?

Tick to indicate willingness to pay.
Cross to indicate you are not willing to pay

Weekly (approx.)	= per year (approx.)
10p	£5
20p	£10
30p	£15
60p	£30
£1	£50
£1.50	£75
£2	£100
£10	£500
£20	£1,000

Attendees at the GYS were intercepted at random and an in-person written survey was conducted. The sampling strategy aimed at maximising the total number of households interviewed and the sample was stratified to make it representative of the temporal distribution of visitors (e.g. different hours of the day). Every fourth individual encountered was invited to participate in the survey (Bateman et al., 2002). Mitchell and Carson (1989) suggested that payments for most public goods are made at the household level. Therefore, only adult members who are 18 years and above were interviewed, and interviewers were instructed to question the household head responsible for making expenditure decisions if family groups were encountered. In total, 345 households were selected and interviewed.

3. Results

3.1. Descriptive statistics

Table 1 gives a summary of the socio-economic characteristics for the sample. A number of key points emerge from the summary statistics. The gender of the sample population is approximately balanced, with 51% of respondents being female. Just under half (48%) of the sample were within the ages 46–60 + years, while 30.1% were between 30 and 45 years and 22.3% were aged between 18 and 29 years. The majority had formal educational qualifications and half (51%) possessed a science qualification. Approximately 90% of the respondents had completed school to the age of 16 and 41% had received further education or university degrees. Income categories range up to £70,000 with a large number of respondents (16.9%) falling in the £30,000–£39,000 income level. The average number of dependants, an indicator of household size is 1 dependant per household. Comparison with statistics for the UK as a whole (Office for National Statistics, 2017) suggests that the sample age structure, gender and income are not significantly different to that of the general UK population (Table 1).

[7] In addition, incentive compatibility requires the stipulation of a provision rule (Champ et al., 2003). In this study, respondents were informed that if at least 50% of participants agreed to pay the tax, the bee protection policy would be implemented.

Table 1
Socio-economic characteristics of Respondents.

Parameters	Sample	National average
Sex ratio (male = 1, female = 0)		
Age distribution (%)	0.49	0.49
18–29 years	22.32	19.90
30–45 years	30.14	20.40
46–60 + years	47.54	42.1
Level of education (%)		
No qualification	10.32	22.70
School certificate (age 16)	12.98	13.30
Higher school certificate (age 18)	11.21	12.3
Further education	18.88	15.3
Honours degree	21.83	27.2
Higher degree (MSc, MA, PhD)	18.29	–
Other qualifications	–	5.7
Annual household income (£'000)		
Income distribution (%)	32.99	35.60
Less than £10k	11.96	
£10k–£14.9k	12.58	
£15k–£19.9k	8.59	
£20k–£24.9k	7.98	
£25–£29.9k	10.74	
£30k–£39.9k	16.87	
£40k–£49.9k	9.51	
£50k–£59.9k	7.67	
£60k–£69.9k	6.13	
Over £70k	7.98	

Notes: national averages were obtained from the UK Office for National Statistics (ONS) for the year 2011.

In terms of being aware of the threat facing bee populations, 84% of the participants were cognisant of the status of bee populations and their decline prior to this survey. This high level of awareness was attributed to UK media coverage of declining bee populations (Breeze et al., 2015). In addition, 16% of the participants interviewed were members of a conservation or wildlife trust. These results indicate an appreciation of environmental issues—but also the bias caused by where the survey took place.

3.2. Willingness to pay results

The following aspects of the respondents' WTP for a bee protection policy were analysed:

1. All respondents were asked whether or not they were prepared to pay anything (the payment principle question).
2. Those who responded positively to (1) were asked to indicate the maximum amount they would be willing to pay per week (in response to a PC format).

Of the 345 respondents, 221 (64%) answered positively to the payment principle question, and 36% were not willing to pay anything to protect bee populations. Following standard practice in CV studies, respondents were asked follow-up questions to screen for possible 'protest' zeros. Those who answered 'no' to the payment principle question were asked to indicate the reasons for their choice. The analysis of reasons given for refusing to pay led to the identification of 26% of protest bidders and 74% of zero bidders.[8] Respondents classified as protesters included those who stated: 'I need more information and time to answer' or that the government should pay (26%). Those who stated that: 'My household cannot afford to pay' (39%); 'I think bees are not a

[8] Note that protest responses can make up 10% of overall responses but can also range up to 20% or even 50% (Mitchell and Carson, 1989). In our study, this includes respondents who rejected the CV scenario, because they did not believe that it will be applied or that the tax issue would be implemented in the way it was presented to them. We thank the anonymous reviewer for making this clarification.

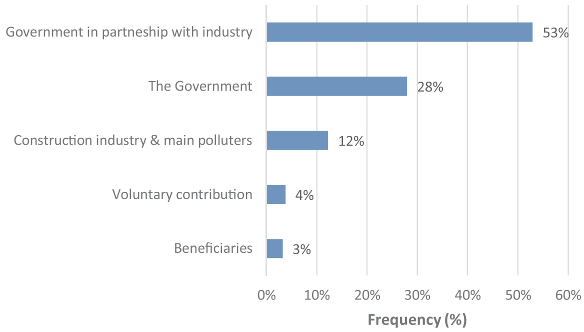

Fig. 1. Respondent perception of who should pay to protect bees in the UK.

high priority' (33%); 'the extra money is insufficient to make any difference' (9%); 'I am not interested in this matter (3%); or "I would be satisfied with the future situation" (2%) were treated as zero bidders. As protest responses do not reflect true WTP, they were excluded from the WTP analysis (Bateman et al., 2002). Importantly, from the point of view of study validity, few respondents appear to object to the fundamental principle of valuing the preservation of bees.

The study also probed respondents' opinions of who should pay for the implementation of a policy to protect bee populations. Fig. 1 is a summary of the results. Many respondents believed that the Government (28%) or the Government in partnership with industry (53%) should pay. About 12% of respondents indicated that those deemed responsible for contributing to lower bee numbers (e.g. the construction industry or the main polluters) should pay for the policy. This reflects the 'polluter pays principle', which instructs that those responsible for causing pollution in the environment should be liable to pay damage costs (Tietenburg and Lewis, 2015). Only 3% of respondents believe that those who directly benefit from bees should pay (e.g., countryside tourism, farmers and beekeepers). However, it can be argued that if farmers are the cause (through pesticide use) and are the beneficiaries, they should also pay.

3.3. WTP estimation

Table 2 shows WTP distribution statistics for the raw PC data. Note that 14% of respondents are willing to pay at least the minimum positive amount on the payment card while 84% were willing to pay the 'break even' amount of £1 per week (Table 2). The survival function illustrated in Fig. 2 shows that the proportion of 'yes' responses declines with the bid amounts in the PC format, as expected.

Table 3 reports the results of the interval regression model. The estimated model is statistically significant ($P < 0.05$) and the coefficients of income, age, gender, number of dependants, membership of conservation and wildlife trust and education were statistically significant ($P < 0.05$) and of the expected signs. The coefficient of household income is positively associated with WTP, which is consistent with economic theory. The coefficient of age is negatively related to WTP for the middle age group (30–45 years) but not in the older age group (46–60 + years), which has a positive sign. Women are more willing to pay, on average, compared to men. The number of dependants (a proxy for the household size) has a negative impact on WTP, possibly because of the lower disposable income. Membership of a wildlife trust or conservation organisation and awareness of declining bee populations has a significant positive effect on WTP. Finally, those respondents who have a science qualification presented a higher probability of expressing a higher WTP than those without such a qualification.

Table 2
WTP statistics.

Amount (£)	Frequency	Proportion of respondents (%)
£0.1	32	14
£0.2	35	16
£0.3	30	14
£0.6	25	11
£1	64	29
£1.50	10	5
£2	15	7
£10	6	3
£20	5	2
Median	£0.6	
Mode	£1	
Maximum	£20	
No. of obs.	222	

The mean WTP estimate was recovered from the interval regression model and the confidence intervals were constructed using bootstrapping (Bateman et al., 2002). The mean WTP and the 95% confidence interval are reported in Table 3. The mean WTP expressed by the total sample is £0.83 per household per week (which is equivalent to £43 per household per year). Further, the welfare estimate was aggregated over the entire sampling population to determine the total WTP (total benefits) to maintain bee numbers in the UK. Using the estimated mean WTP of £43 per household per annum and the total number of UK taxpayers in 2009 (30.6 million from the UK Office of National Statistics, 2017), this amounts to a total annual value of about £1.32 billion per year. However, it assumes that all working adults in the UK (30.6 million) would have been willing to pay the values reported in Table 3. If we adjust for the proportion of the sample that agreed to pay the tax increase (0.64), then a more conservative estimate would be £842 million per annum. This figure is an estimate of the total value of public support to protect bees in the UK and is significantly larger than the estimate of pollination services provided to crop production (£430 million per year).

4. Discussion

A number of key issues emerge from this study. Firstly, it is recognised that the survey sample used in this study was relatively small and does not entirely capture the full profile of the UK population. More generally, a major proportion of the respondents could have reasons to be concerned by pollinator matters due to the bias caused by the survey at GYS.

The second issue relates to the contingent valuation of pollination. In general, it is challenging to use SP methods to value services that include a strong use-value component because it is too difficult to separate use value from non-use value in the CV and because of the possibility that subjects may overstate use values (Hanley et al., 2015).[9] In this study, it was not clear whether individuals truly have a high non-use value for bees (given that the WTP is higher than the previous estimates of the market value of pollination service) or whether the individuals hold small non-use values and are simply stating high estimates of pollination use values. More research is needed to validate our preliminary findings of the non-market values of pollination services. It is suggested that future studies should distinguish between the value assigned to wild bees and that attributed to honey bees but also between the value people assign to the pollination of wild flora compared to crops.[10]

The third issue regards hypothetical bias in CV responses (Murphy

[9] For example, a further challenge is that honeybee pollination services in the UK are already paid for. A reviewer pointed out that "there are pollinator rentals and therefore, bee pollination services are in the market. Further, honey is a positive externality for honey bee pollination". However, the benefits of pollination services are much more widespread and the intent of this paper was to examine the non-market values of pollination services including non-use values. We thank the reviewer for his comment.

[10] It should be noted that it does not matter the source, if the goal is to value pollination. But it matters if you are valuing the pollinator. We thank the reviewer for prompting this clarification.

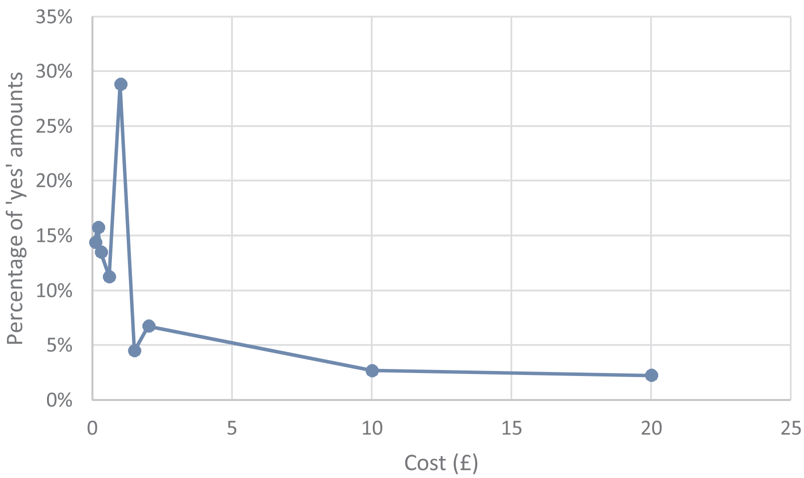

Fig. 2. Survival function for the PC response.

Table 3
Estimated interval regression model of WTP.

	Coefficient	Standard error	*t*-statistics
Income	0.0092	0.0051	2.81**
Number of dependants	−0.3100	0.2228	−2.39**
Age (30–45 years)	−0.0381	0.2998	−2.13
Age (46–60+ years)	0.5474***	0.1927	2.84**
Gender	0.0476	0.1901	2.25
Member of conservation/wildlife trust	0.7195	0.2580	2.79**
Science qualification	0.3899**	0.2034	2.92**
Constant	−0.4043	0.3069	−1.32
Sigma	1.6407	0.0692	
Log-likelihood	−831.87		
Chi-square value (7)	29.24		
Number of observations	316		
Mean WTP (£)	£0.83		
95% CI (£)	£0.64–£1.01		

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

et al., 2005). The issue of hypothetical bias was addressed in this study through the use of a cheap talk script but also through the development of a consequential questioning strategy, coupled with a provision rule (Carson and Groves, 2007). The survey was designed so that participants perceived it as consequential, with a coercive payment mechanism (a tax). The questionnaire was put to respondents as a way for government to collect information to develop policy (i.e. answers people gave had consequences). We included a provision rule that respondents would have to pay if the majority agreed to pay the nominated amounts (a 50% provision rule). However, although hypothetical bias was mitigated in these ways, the lack of a hard spending constraint implies that hypothetical WTP may exceed actual WTP and estimates of WTP may be overstated.

Fourthly, there are currently few assessments of the non-market values of pollination services utilising stated preference techniques. At present only one paper has provided SP estimates of either direct or indirect non-market benefits of pollinators (Breeze et al., 2015). Breeze et al. used a choice experiment (CE) survey to examine the UK public's WTP to conserve bee pollinators in relation to the levels of two pollination service benefits: maintaining UK grown produce availability and the aesthetic benefits of diverse wild flowers. They estimated a total WTP of £13.4 per UK tax payer, producing an aggregate WTP of £379 million over the sample of the tax-paying population of the UK. Our CV WTP estimate of £43 per UK household is slightly larger than the estimates of Breeze et al. (£13.4 per tax payer) but is within the same order of magnitude.[11] As elaborated in this paper, different methods produce different estimates of values, with the CE producing the smaller estimate of WTP compared to the CV. A number of methodological issues may further explain the differences between the value estimates including for example, the sample size, functional forms, and the estimation and aggregation procedures implemented in these two studies (Breeze et al., 2016).

Finally, it is important to consider the possible policy response in order to protect the bee population in the UK. The UK has had conservation strategies for pollinators, including support for hedgerows, riparian areas, prairies and policy on pesticide. Therefore a key question is: what further policy support is needed to protect bees? And what is the efficiency (the benefits per unit cost) of the bee protection policy? Total income from agriculture in the UK was estimated to be £3769 million in 2015, and the gross value added (GVA) which represents agriculture's contribution to the Gross Domestic Product (GDP) was £8495 million, in real terms (DEFRA, 2016). Agricultural subsidies are distributed in accordance with the Common Agricultural Policy (CAP) of the EU. Total direct payments in the UK were £2.80 billion in 2015 (DEFRA, 2016). Approximately £488 million is spent on agri-environment schemes (AES) which is mostly focussed on biodiversity—including pollinators (DEFRA, 2016).[12] The CV estimate of total benefits ($842 million per annum) is significantly higher than the total spending on biodiversity, with an indicative benefit/cost ratio of 2:1. Hence the bee protection policy passes the cost-benefit test. Our analysis provides support for policy makers and other stakeholders in agriculture and conservation to consider policy responses required to protect pollinators. We suggest that a possible policy response would be to further inform the UK population about the status of bee populations and the positive externalities of bees for pollination.

5. Conclusions

The key conclusion drawn from the CV data is that the public has positive valuation preferences for the protection of bees. The mean WTP to support the bee protection policy was £43 per household per annum, equivalent to £842 million per annum. This economic valuation can be used as a means of illustrating the public support for conserving pollinators to policy makers and other stakeholders.

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[11] If we divide the average WTP per household derived from the CV by the average household size in the UK (2.4 persons per household, from the UK Office of National Statistics, 2017), we get an average WTP of 18 per person which is close to the estimate of Breeze et al of $13 per tax payer.

[12] These schemes pay farmers to adopt conservation practices that are beneficial to the environment and biodiversity. In general AES have been shown to improve bee diversity and abundance on farms and at the landscape scale (see for example Carvell et al., 2007 and references therein).

and analysis, decision to publish or preparation of the manuscript. We thank Mildred Reiners, Holly Richardson, Kate Parker, Selwyn Wilkins and Ben Jones from the National Bee Unit, and Andrew Cuthbertson and Helen Anderson from Fera for their contribution to this study.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.landusepol.2017.11.045.

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